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Alcohol and Cannabis Use for Sleep Aid in College Students: A Daily Diary Investigation of Proximal Outcomes

Patricia A. Goodhines
Syracuse University

Abstract

Emerging evidence suggests that one in five college students use substances such as alcohol and/or cannabis to help sleep. Despite this high prevalence of sleep aid use, there remains a dearth of research on its potential proximal sleep- and substance-related consequences day-to-day. The current study remedied this literature gap by examining how alcohol and cannabis sleep aid use impacted subsequent sleep and substance use consequences among college substance users. Out of the baseline sample of 217 students, 83 past-month alcohol and/or cannabis sleep aid users (mean age = 19.33 [*SD* = 1.11], 30% male, 72% White) completed online questionnaires for 14 consecutive days to assess sleep aid use, sleep, substance use, and negative substance consequences. After controlling for daily cannabis use frequency, cannabis sleep aid use was associated with longer sleep duration and more negative cannabis consequences on average across 14 days, as well as longer same-night sleep duration, reduced same-night wake-time after sleep onset, and higher next-day daytime fatigue compared to individual averages. After controlling for daily alcohol quantity, alcohol sleep aid use was not associated with sleep-related outcomes or negative drinking consequences compared to either sample or individual averages; null findings may be due to a low frequency of alcohol sleep aid use over 14 days (1%). Results highlight daytime fatigue and negative cannabis consequences as potential adverse short-term outcomes of cannabis sleep aid use among college students, despite its proximal sleep-related benefits. This novel daily-level investigation contributes substantially to our limited understanding of college sleep aid use and associated proximal consequences.

Keywords: sleep aid, alcohol, cannabis, consequences, fatigue, daily diary, multilevel, college

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Patricia A. Goodhines

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College students are at high risk for sleep problems and associated psychosocial consequences. More than 70% of college students do not attain the recommended amount of sleep for their age group (Hirshkowitz et al., 2015; Lund et al., 2010) and 51 – 66% of students endorse poor subjective sleep quality (Kenney et al., 2014; Lund et al., 2010; Vargas, Flores, & Robles, 2014). Among college students, insomnia symptoms are concurrently associated with higher negative mood and suicidal ideation (Nadorff, Nazem, & Fiske, 2011; Taylor et al., 2013), as well as greater quantity, frequency, and negative consequences of alcohol use (DeMartini & Fucito, 2014). Likewise, poor sleep quality during college is prospectively associated with increased next-day negative affect (Simor et al., 2015) and more negative mood across the academic year (Wong et al., 2013) and insomnia symptoms during college are associated with increased emotion regulation difficulty up to two years later (Tavernier & Willoughby, 2015).

Alcohol and cannabis use for sleep aid is prevalent among college students and is potentially associated with adverse consequences. Studies of college sleep aid use found that 7 – 11% of students used alcohol and 14 – 15% of students used cannabis to help sleep (Goodhines et al., 2017; Lund et al., 2010; Taylor & Bramoweth, 2010). A recent study found that alcohol and cannabis sleep aid use (i.e., alcohol, cannabis, and over-the-counter medication) was concurrently associated with more severe insomnia symptoms, more frequent alcohol use and binge drinking, and more negative alcohol consequences (Goodhines et al., 2017). This same study also found that sleep aid use was associated with greater increases in negative alcohol consequences, but no change in insomnia symptom severity, two months later. These results

suggest that sleep aid use does not achieve the intended function of improving sleep, but instead results in unintended negative alcohol consequences across this short-term timeframe.

Further investigation into college students' prevalent alcohol and cannabis sleep aid use may be guided by theory from the substance use literature. Self-medication theory posits that substances may be consumed to ameliorate subjective states of distress (Khantzian, 1985, 1997). Indeed, alcohol and cannabis sleep aid use may serve to relieve negative pre-sleep affective states characterized by dysfunctional beliefs about sleep, unpleasant intrusive thoughts, and uncontrollable worry (Harvey, 2002). However, the decision to self-medicate is likely shaped by factors beyond momentary affective state, such as individual self-regulatory vulnerabilities (Khantzian, 1985, 1997), outcome expectancies informed by peer norms and past experience (as in Social Learning Theory; Maisto, Carey, & Bradizza, 1999), and substance use motives (Cooper, 1994; Cox & Klinger, 1988, 2011). While little is known about antecedents to alcohol and cannabis sleep aid use among college students, comparably little is known about associated consequences (see Goodhines et al., 2017). This gap in the literature is significant given the theoretical view that substance use behavior motivated by different needs (e.g., sleep) is characterized by unique patterns of consequences (see Cooper, 1994). Thus, the current paper seeks to further investigate potential consequences of this prevalent and uniquely-motivated pattern of substance use for sleep aid.

Regarding potential consequences, according to Brower's theory of the reciprocal associations between insomnia and alcoholism (2001, 2003), alcohol use for sleep aid is an integral part of a negative feed-forward cycle exacerbating both sleep and alcohol problems over time. This model posits that insomnia symptoms (e.g., difficulty falling asleep) prompt individuals to self-medicate with alcohol to help initiate sleep. However, in contrast with its

sleep-initiating effect and consequent perceived function as a chemical "sleep aid" (Harvey, 2002, 2005), as little as one drink can result in exacerbated insomnia symptoms during the night (for a review, see Ebrahim et al., 2013) due to toxicity on sleep-related brain systems. While sleep disturbance persists, individuals repeatedly consume alcohol for sleep aid and eventually require higher doses to attain the desired sleep-initiating effects. Consequently, individuals are placed at increased risk of developing alcohol use disorder and negative drinking consequences over time. In order to address emerging evidence suggesting high prevalence of both alcohol and cannabis sleep aid use among college students, the current study extends Brower's theory (2001, 2003) by additionally considering cannabis sleep aid use and investigating theorized associations among a sample of college alcohol and/or cannabis users (rather than adult alcoholics).

Experimental evidence for the sleep-promoting effects of alcohol and cannabis (for a review, see Ebrahim et al., 2013; Garcia & Salloum, 2015; Schierenbeck et al., 2008) is largely consistent with Brower's theory, with a few key differences. Indeed, pre-sleep alcohol administration resulted in improved subjective sleep quality (Roehrs, Petrucelli, & Roth, 1996), possibly reflecting observed reductions in sleep onset latency (Finnigan, Hammersley, & Cooper, 1998; Roehrs et al., 1999). However, pre-sleep alcohol administration also resulted in decreased objectively-measured sleep duration in the second half of the sleep period (Arnedt et al., 2011), increased wake-time during the night (Arnedt et al., 2011; Roehrs, Yoon, & Roth, 1991; Williams, MacLean, & Cairns, 1983), and greater subjective fatigue the following day (Chait & Perry, 1994) due to rapid eye movement (REM) sleep suppression and consolidation of sleep in the first half of the sleep period. Similar to alcohol, pre-sleep cannabis administration resulted in greater sleep satisfaction (Bedi et al., 2010; Haney et al., 2007), as well as increased next-day fatigue (Chait, Fischman, & Schuster, 1985) due to slow chemical elimination. Unlike alcohol,

cannabis extended total sleep time and reduced wake-time after sleep onset (Feinberg et al., 1975; Tassinari et al., 1999) due to the suppression of REM sleep and enhancement of slow wave sleep across the full sleep period. Notably, evidence for associations of pre-sleep alcohol and cannabis use with sleep from experimental studies (e.g., Bedi et al., 2010; Chait et al., 1994; Roehrs et al., 1991; Tassinari et al., 1999) and community samples (e.g., Arnedt et al., 2011; Feinberg et al., 1975; Wadsworth et al., 2006) may not accurately generalize to proximal day-to-day associations among college students.

Although Brower's theory (2001, 2003) posits that sleep aid use leads to increased substance use and problems over time, evidence for this proposed pathway is both limited and mixed. Adults with insomnia are more likely to develop alcohol use disorder the following year (Weissman et al., 1997) and are more likely to consume alcohol before bed (Roehrs et al., 1999) compared to adults without insomnia. Likewise, individuals with insomnia are more likely to report co-occurring drug use (including cannabis) compared to healthy sleepers (Breslau et al., 1996). The sleep-initiating effects of both alcohol and cannabis use develop quickly (i.e., within 3 – 8 days of consecutive use; Bedi et al., 2010; Rundell et al., 1972), suggesting that sleep aid users require increased dosages over time. Collectively, these findings provide some support for Brower's claim that self-medication of sleep problems serves as a pathway to alcohol problems (2001, 2003). Unfortunately, evidence for this association among college students remains sparse. A recent study found that alcohol and cannabis sleep aid use did not promote increased alcohol use over a 2-month period, but did exacerbate the negative consequences of existing alcohol use (Goodhines et al., 2017). These mixed findings across two alcohol outcomes might be explained by the 2-month timeframe of the study, which may have been too narrow to capture increases in alcohol use potentially developing over a longer period of time; alternatively,

findings may suggest the potential for nuanced, heretofore uninvestigated short-term changes in associations of sleep aid use with negative substance use consequences occurring in day-to-day life.

Several important gaps remain in the growing literature on associations of alcohol and cannabis sleep aid use with sleep- and substance-related outcomes. First, investigation of college students is limited, despite evidence that college years typically represent a developmental stage (i.e., emerging adulthood; Arnett, 2016; National Center for Education Statistics, 2016) characterized by uniquely irregular sleep patterns (Hirshkowitz et al., 2015; Maslowsky & Ozer, 2014) and prevalent alcohol and cannabis use (Johnston et al., 2015; Substance Abuse and Mental Health Services Administration, 2014). Second, empirical investigation of cannabis use for sleep aid remains lacking, despite demonstrated prevalence (Goodhines et al., 2017). Lastly, intensive assessment methods are needed to examine nuanced associations between sleep aid use and sleep- and substance-related outcomes within students in daily college life. While previous findings of between-person associations provide valuable information about average differences between individuals, little is known about how individuals may vary around their own personal averages day-to-day as a function of sleep aid use. In contrast to previous study designs, daily diary assessment methods are well-equipped to investigate these daily-level associations within individuals (Bolger & Laurenceau, 2013; Gunthert & Wenze, 2012).

Study Aims and Hypotheses

The aim of the current study was to examine the potential adverse impact of daily alcohol and cannabis sleep aid use on proximal sleep-related outcomes (i.e., same-night poor sleep quality rating, same-night sleep duration, same-night wake-time after sleep onset, and next-day daytime fatigue) and next-day negative alcohol and cannabis consequences measured

subjectively among college students. The current study utilized a daily diary design to comprehensively monitor participants' sleep aid use, sleep, substance use, and substance use consequences as they navigated through their day-to-day lives, thus allowing for the examination of both average between-person differences and within-person change across a 14-day period.

It was hypothesized that both alcohol and cannabis sleep aid use would be associated with improved same-night sleep quality rating, but increased next-day daytime fatigue, compared to both sample and individual averages. Further, it was hypothesized that alcohol sleep aid would be associated with decreased same-night sleep duration and greater wake-time after sleep onset, while cannabis sleep aid would be associated with increased same-night sleep duration and decreased wake-time after sleep onset, compared to both sample and individual averages. Lastly, it was hypothesized that alcohol sleep aid use would be associated with more next-day negative alcohol consequences and cannabis sleep aid use would be associated with more next-day negative cannabis use consequences compared to both sample and individual averages.

Method

Participants

Data were obtained from 217 undergraduate students (mean age = 19.38 [*SD* = 1.17], 24% male, 73% White) recruited from an introductory psychology course (*n* = 77) and advanced psychology courses (*n* = 140) at a four-year university in the northeastern United States. Students were compensated with either research-credit or extra-credit points for their course, scaled according to the number of surveys completed. Participants were eligible if they: (a) were an undergraduate student; (b) were aged 18-25 years; (c) were English-speaking; (d) had used alcohol and/or cannabis at least once during the past 30 days. Age restrictions were implemented to accurately capture the sleep experiences of "young adults," consistent with National Sleep

Foundation recommendations (Hirshkowitz et al., 2015). The substance use eligibility criterion was implemented to maximize the probability of capturing the primary phenomena of interest (i.e., alcohol and cannabis sleep aid use). A subset of 83 students (mean age = 19.33 [*SD* = 1.11], 30% male, 72% White) who endorsed past-month alcohol and/or cannabis use for sleep aid at baseline were selected for daily multilevel analysis (see Data Analytic Strategy).

Procedure

Institutional review board approval was obtained for all study procedures. Study procedures were piloted with a focus group (n = 8) in the spring 2017 semester to assess feasibility and revise accordingly prior to commencement of full data collection. Full data collection commenced 2 weeks into the fall 2017 semester, avoided week-long university breaks, and concluded prior to final examinations. The study was advertised to students as "College Sleep Study." Interested students were contacted for a brief phone-screening to confirm eligibility. Eligible students were scheduled for a 1-hour appointment in the research lab.

Upon arrival to the lab, participants provided written informed consent. Participants completed a baseline web-based survey and obtained instructions for completing web-based "daily waking surveys" for the following 14 days. The 14-day time frame is consistent with the modal assessment period among daily-assessment literature (Gunthert et al., 2012) and recommendations for daily sleep assessment (Buysse et al., 2006). This 14-day time frame has demonstrated the capacity to reliably capture change over time in sleep, substance use, and affect/stress among college students (e.g., Fairlie, Maggs, & Lanza, 2015; Patrick, Yeomans-Maldonado, & Griffin, 2016; Winzeler et al., 2014). Beginning the Monday following their lab appointment, via preferred method of email or text message, participants received a link for the daily waking survey at 6:00 a.m. each morning and a reminder at 11:00 a.m. if needed. A daily

deadline of 3:00 p.m. was implemented for survey completion to control for the unintentional priming of sleep aid use prior to sleep in the evening and retroactive completion of previous days' surveys.

Measures

Baseline survey.

Sleep aid use. Two items adapted from a previous study (Gellis et al., 2014; Goodhines et al., 2017) were used to assess frequency of using alcohol and cannabis "to help sleep" during the past month. The original response scale was adjusted for the past month, such that items were rated on an 8-point Likert scale ranging from 0 (*I did not use this substance to help fall asleep in the past month*) to 7 (*every day*). Individual dichotomized scores (i.e., 0 = *no*, 1 = *yes*) were used for analyses.

Sleep and associated functioning. The 19-item Pittsburgh Sleep Quality Index (Buysse et al., 1989) subjectively measured both quantitative (e.g., sleep duration, weekly frequency of waking after sleep onset) and qualitative (e.g., sleep quality rating) aspects of sleep. Global index scores (possible range = 0 – 21) of five or greater indicate significant sleep disturbance (Buysse et al., 1989). This measure has demonstrated good test-retest reliability and construct validity (Backhaus et al., 2002) and is therefore recommended as a standard measure for global sleep (Buysse et al., 2006).

The 9-item Fatigue Severity Scale (Krupp et al., 1989) assessed participant agreement with statements regarding daytime fatigue (e.g., "Fatigue causes frequent problems for me."). Response options were based on a 6-point Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). A sum score was used for analyses (Cronbach's $\alpha = .90$), with higher scores indicating a more severe fatigue.

Alcohol use and related problems. Two items recommended by the National Institute on Alcohol Abuse and Alcoholism (2003) measured frequency and quantity of alcohol use in the past month. For example, frequency of alcohol use was assessed by asking participants "During the past month, how often did you usually have any kind of drink containing alcohol?" with response options based on an 8-point Likert scale ranging from 0 (*I did not drink any alcohol in the past month*) to 7 (*every day*). Individual scores of each alcohol use variable were used for analyses.

The 48-item Young Adult Alcohol Consequences Questionnaire (Read et al., 2007) assessed perceived experiences of negative consequences due to alcohol use. Participants indicated whether they experienced diverse negative alcohol consequences (i.e., 0 = *no*, 1 = *yes*) during the past month. For example, sample items included "I have become very rude, obnoxious or insulting after drinking," "I have taken foolish risks when I have been drinking," and "I have awakened the day after drinking and found that I could not remember a part of the evening before." The timeframe of the original measure was adapted from the past 6 months. A count score was used for analyses. This measure has demonstrated reliability and predictive validity among college students (Read et al., 2007) and is commonly used to assess negative alcohol consequences among college student samples (e.g., Bravo et al., 2018).

Cannabis use and related problems. One item adapted from the Global Appraisal of Individual Needs-I (Dennis et al., 1999) assessed frequency of cannabis use during the past month (i.e., "During the past month, how often did you usually use any kind of cannabis or hashish?"). Consistent with the aforementioned alcohol frequency item, the response scale was revised to an 8-point Likert scale ranging from 0 (*I did not use any cannabis in the past month*) to 7 (*every day*). Cannabis quantity was not assessed because quantification of cannabis

consumed can be difficult due to variability in administration method and lack of standardization (Baggio et al., 2014; Cuttler & Spradlin, 2017) and is consequently often inaccurate (Prince, Conner, & Pearson, 2018).

The 50-item Marijuana Consequences Questionnaire (Simons et al., 2012) assessed perceived experiences of negative consequences due to cannabis use. Participants indicated whether they experienced negative cannabis consequences (i.e., 0 = *no*, 1 = *yes*) during the past month. Items were adapted directly from the Young Adult Alcohol Consequences Questionnaire (Read et al., 2007) and sample items included "I have become very rude, obnoxious, or insulting after using marijuana," "I have taken foolish risks when I have been high," and "I have awakened the day after using marijuana and found I could not remember a part of the evening before." The timeframe of the original measure was adapted from the past 6 months. A count score was used for analyses. This measure has demonstrated convergent and discriminant validity among college students (Simons et al., 2012) and is commonly used to assess negative cannabis consequences among college student samples (e.g., Phillips et al., 2014).

Tobacco use. One item adapted directly from the preceding cannabis item assessed frequency of tobacco use during the past month (i.e., "During the past month, how often did you usually use any kind of tobacco?"). Consistent with the aforementioned alcohol frequency item, the response scale was revised to an 8-point Likert scale ranging from 0 (*I did not use any tobacco in the past month*) to 7 (*every day*).

Demographics. Sex, age, class year, race, country of origin, full-time student status (0 = *full-time*, 1 = *part-time*), working status (0 = *full-time*, 1 = *part-time*, 2 = *not working*), residence type (0 = *off campus*, 1= *on campus*), and Greek fraternity/sorority affiliation (0 = *non-member*, 1 = *member*) were assessed. Demographic variables were selected based on previous findings

demonstrating associations with alcohol and cannabis use (e.g., LaBrie, Grossbard, & Hummer, 2009; LaBrie et al., 2011; Park, Sher, & Krull, 2009) and sleep behaviors (Galambos et al., 2013; Lund et al., 2010; Taylor et al., 2010) among college students.

Negative mood. The 4-item Patient Health Questionnaire assessed subjective frequency of negative mood (i.e., depression and anxiety symptoms; Kroenke et al., 2009). Participants indicated how often they "felt bothered by" the following problems during the past month: "feeling nervous, anxious or on edge," "not being able to stop or control worrying," "little interest in pleasure in doing things," and "feeling down, depressed, or hopeless." The timeframe of the original measure was adapted from the past 2 weeks and response options were based on a 4-point Likert scale ranging from 0 (*not at all*) to 3 (*nearly every day*). A sum score was used for analyses (Cronbach's $\alpha = .81$), with higher scores indicating more frequent depression and/or anxiety symptoms. This brief scale has been shown to be a reliable and valid measure of negative mood among college students (Khubchandani et al., 2016; Löwe et al., 2010).

Daily waking surveys.

Substance use for sleep aid and non-sleep aid. Participants were presented with one item assessing alcohol quantity (i.e., "How many drinks containing alcohol did you have yesterday?"). If students endorsed any alcohol use, they were then presented with six items selected and/or adapted from the Drinking Motives Questionnaire (Cooper, 1994) to assess daily alcohol sleep aid use and other daily alcohol use (i.e., non-sleep motive). Participants were presented with the prompt, "When you used alcohol yesterday, did you use for any of the following reasons? Check all that apply." and responses were coded dichotomously (i.e., 0 = *no*, 1 = *yes*). Items included "To forget your worries," "So that others won't kid you about not drinking," "Because it's exciting," "Because it makes social gatherings more fun," "To help sleep," and "None of these."

Items selected include the highest loading item from each of the four factors in the original measure (Cooper, 1994) as determined by factor analysis with a sample of Syracuse University students (i.e., sample reported on in Goodhines et al., 2017), along with an investigator-developed sleep-motive item (i.e., "To help sleep") to isolate alcohol sleep aid use. Similar adaptations of this measure have been used previously for studies of event-level drinking in college students (e.g., Kilwein & Looby, 2018).

Participants were likewise presented with one item assessing cannabis frequency (i.e., "How many times did you use marijuana yesterday?"). If students endorsed any cannabis use, they were then presented with seven items selected and/or adapted from the Marijuana Motives Questionnaire (Simons et al., 1998) to assess daily cannabis sleep aid use and other daily cannabis use (i.e., non-sleep motive). Participants were presented with the prompt, "When you used marijuana yesterday, did you use for any of the following reasons? Check all that apply." and responses were coded dichotomously (0 = *no* and 1 = *yes*). Items included "To forget my worries," "Because I like the feeling," "Because it makes social gatherings more fun," "To be liked," "To expand my awareness," "To help sleep," and "none of these." Consistent with alcohol use motives, items selected include the highest loading item from each of the five factors from the original measure among a college student sample (Simons et al., 1998), along with an investigator-developed sleep-motive item (i.e., "To help sleep") to isolate cannabis sleep aid use. Similar adaptations of this measure have been used previously for studies of event-level cannabis use in young adults (e.g., Shrier et al., 2017).

Participants were presented with one item assessing tobacco frequency (i.e., "How many times did you use tobacco yesterday?").

Sleep and associated functioning. Twenty-one items regarding daily sleep and substance use were selected and/or adapted from the Expanded Consensus Sleep Diary for Morning (Carney et al., 2012). Specific items relevant to the current daily analyses include poor sleep quality rating (i.e., "How would you rate the quality of your sleep?"; responses options: 0 [*very good*] to 5 [*very poor*]), sleep duration (i.e., "In total, how long did you sleep?"; responses were scaled to hours for analyses), wake-time after sleep onset (i.e., "How many times did you wake up, not counting your final awakening?" followed by "In total, how long did these awakenings last?"; responses were scaled to minutes for current analyses), and daytime fatigue (i.e., "How fatigued did you feel during the day yesterday?"; response options: 0 [*not fatigued*] to 4 [*very fatigued*]).

Negative alcohol consequences. Daily negative alcohol consequences were assessed using 22 items selected from the Brief Young Adult Alcohol Consequences Questionnaire (Kahler, Strong, & Read, 2005). Consistent with previous event-level assessments of alcohol consequences among college students (e.g., Hummer et al., 2013), two items not deemed appropriate for a daily-level assessment were excluded from the original 24 items (i.e., "I have been overweight because of my drinking" and "My physical appearance has been harmed by my drinking"). The wording of the original items was also adapted as needed to fit the context of previous-day drinking episodes (e.g., the original "I have passed out from drinking" was changed to "I passed out from drinking"). Participants were presented with the prompt, "Below is a list of things that sometimes happen to people either during or after they have been drinking alcohol. Did any of these things happen while/after you drank yesterday? Check all that apply." and responses were coded dichotomously (i.e., 0 = *no*, 1 = *yes*). A count score was used for analyses.

This measure has been used previously in diary studies of college substance use (e.g., Pearson, D'Lima, & Kelley, 2013).

Negative cannabis consequences. Daily negative cannabis consequences were assessed using 14 items selected from the Brief Marijuana Consequences Questionnaire (Simons et al., 2012). As with the assessment of daily alcohol consequences, items were presented in a single checklist form and seven items not considered appropriate for a daily-level assessment were excluded from the original 21 items (e.g., "I have received a lower grade on an exam or paper than I ordinarily could have because of marijuana use"). The wording of the original items was also adapted as needed to fit the context of previous-day cannabis use episodes (e.g., the original "I have driven a car when I was high" was changed to "I drove a car while I was high"). Participants were presented with the prompt, "Below is a list of things that sometimes happen to people either during or after they have been using marijuana. Did any of these things happen while/after you used marijuana yesterday? Check all that apply." Participants were then presented with a checklist form of the remaining 14 items and asked to respond to each item dichotomously (i.e., 0 = *no*, 1 = *yes*). A count score was used for analyses. This measure has been used previously in diary studies of college substance use (e.g., Bravo et al., 2017).

Affect, stress, and health. A 4-item adaptation of the Positive and Negative Affect Schedule – Expanded Version (Bagozzi, 1993; Watson, Clark, & Tellegen, 1988) assessed daily negative affect (i.e., depressive and anxious), consistent with a previous daily study of college students (Armeli, Sullivan, & Tennen, 2015). Participants ranked their level of affect (i.e., sad, dejected, jittery, and nervous) during the past 24 hours on a 5-point Likert scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). The timeframe of the original measure was adapted from the past week. A composite score (Cronbach's $\alpha = .85$) was used for analyses.

One item, "Overall, how stressful was your day yesterday," (Kuhlken et al., 2014; O'Hara et al., 2014) assessed daily perceived stress on a 7-point Likert scale ranging from 1 (*not at all stressful*) to 7 (*extremely stressful*). One additional investigator-developed item, "How well do you feel you handled your stress yesterday," assessed daily poor stress tolerance on a 7-point Likert scale ranging from 1 (*very well*) to 7 (*not very well*).

Daily physical health symptoms were assessed using a shortened 10-item version of Larsen & Kasimatis' (1991) symptom checklist, consistent with studies of daily life (e.g., Mallers, Almeida, & Neupert, 2005). Symptoms (e.g., coughing, stomachache, chest pain) were presented as a checklist and participants responded dichotomously (i.e., 0 = *no*, 1 = *yes*). A count score was used for analyses.

Data Analytic Strategies

Descriptive analyses. Descriptive statistics for both baseline variables and daily variables were computed using SPSS Version 24.0 (IBM Corp., 2016). To compare sleep aid users (i.e., participants who endorsed alcohol and/or cannabis sleep aid use at least once during the past month at baseline; $n = 83$) and non-sleep aid users ($n = 134$), independent-sample *t*-tests were computed for continuous study variables (e.g., age) and chi-square analyses were computed for categorical variables (e.g., sex). Bivariate correlations among study variables (i.e., Pearson's correlation coefficients for two continuous variables, Spearman's coefficients for continuous and dichotomous variables, and phi coefficients for two dichotomous variables) were computed with baseline and daily variables.

Multilevel models. Multilevel models were employed for main analyses using daily data only for participants who endorsed past-month alcohol and/or cannabis use for sleep aid at baseline ($n = 83$). Multilevel models examined associations of daily alcohol sleep aid use (see

Table 3) and daily cannabis sleep aid use (see Table 4) with daily sleep-related outcomes (i.e., same-night poor sleep quality rating, same-night sleep duration, same-night wake-time after sleep onset, and next-day daytime fatigue) and negative substance consequences (i.e., alcohol and cannabis, respectively). Analyses for continuous outcomes (i.e., sleep-related outcomes) were conducted using the MIXED procedure in *SPSS*, Version 24.0 (IBM Corp., 2016); maximum likelihood estimation was utilized, as recommended for larger sample sizes (Bolger et al., 2013). Analyses for count outcomes (i.e., negative alcohol and cannabis consequences) were estimated in *Mplus*, Version 7.4 (Muthén & Muthén, 2012), where maximum likelihood estimation with robust standard errors was utilized to account for non-normal distributions (Graham, Cumsille, & Elek-Fisk, 2003). Both count outcomes demonstrated either comparable or superior model fit (i.e., lesser values of Akaike Information Criterion and sample-size adjusted Bayesian Information Criterion) using a negative binomial distribution relative to a Poisson distribution and thus results from the former are reported herein.

In all multilevel models, full information maximum likelihood estimation was used to handle missing data; thus, the full sample (regardless of missing observations) was included. Results from ancillary data analyses with only complete data were consistent with results from all available data reported herein. Because standardized coefficients for multilevel models are difficult to interpret and are not generalizable across samples (see Hox, 2010), unstandardized coefficients are presented herein for an effect-size measure of predictor variables (see Tables 3 and 4). Incidence rate ratios (IRR) and 95% confidence intervals are additionally reported for an effect-size measure of predictor variables in models of count outcomes.

First, unconditional multilevel models (i.e., with no predictors) were estimated for each outcome to calculate the percentage of total variance in the outcome due to between-person

(versus within-person) differences across time: that is, the Intraclass Correlation Coefficient (ICC). ICCs of 1.0 suggest that 100% of variability in the outcome is located between-participants (versus within-participants). For daily diary studies, it is typical to have ICCs in the .20 – .40 range, suggesting dependency due to repeated observations within people and therefore justifying the use of multilevel models (Bolger et al., 2013). A first-order autoregressive covariance structure was used for all models to account for autocorrelation in the repeated daily measures, which allowed the residuals from proximal days to be more similar than those from more distance days. This strategy allowed for temporal carryover; for example, the possibility that the events on one day impact the outcome not only on that day, but also on the following day (i.e., lagged effect; Wickham & Knee, 2013).

***Model specification*.** Level 2 was defined by participants (n = 83) and Level 1 was defined by study days (n = 14) nested within participants. Between-person differences (sample-mean centered) were separated from within-person fluctuations in daily predictors (person-mean centered; as recommended by Aiken & West, 1991; Enders & Tofighi, 2007). Fixed effects at level 2 (i.e., between-person predictors) include average sleep aid use. Fixed effects at level 1 (i.e., within-person predictors) include daily sleep aid use and lagged sleep aid use (e.g., same-day and previous-day). Random effects at level 2 (i.e., extent to which people differ from the group average) allow for each participant to have a unique regression equation. Random effects at level 1 (i.e., extent to which individual data points vary from values predicted by the model) capture residual measurement error. Random effects at level 1 were not calculated for models of count outcomes because *Mplus* (Muthén et al., 2012) is unable to incorporate adjustments to the residual structure at level 1 and therefore cannot allow for residual autocorrelation when working with intensive longitudinal data (Bolger et al., 2013).

Covariates. A mean-centered, linear time trend scaled to units of weeks (i.e., 14 study days represented as values ranging from -1 to +1) was included as a fixed effect at level 1 in all models to account for any unexpected effects of the passage of study days on the outcomes (as recommended by Bolger et al., 2013). A random effect for study days at level 1 also allowed for each participant's study days slope to vary from the group average. In addition, to account for day-of-the-week effects typically observed in substance use and consequences (e.g., Bravo et al., 2017; Finlay et al., 2012), a dichotomized weekend variable (i.e., Friday and Saturday versus weekdays) was included as a fixed effect at level 1 in all models. Thus, model intercepts reflect the estimated value of the outcome for the average person, on an average weekday, at their personal average level of sleep aid use (after accounting for additional covariates cited below).

Additionally, sex and baseline age were sample-centered and included as fixed effects at level 2 in all models. Given the potential effects of negative affect and substance use on daily sleep- and substance-related outcomes, fixed effects for both between-person (level 2) and within-person (level 1) daily negative affect and alcohol quantity and/or cannabis frequency were included as covariates; the model predicting daily negative alcohol consequences controlled only for daily alcohol quantity (not cannabis frequency) and the model predicting daily negative cannabis consequences controlled for daily cannabis frequency (not alcohol quantity) as well as daily tobacco frequency (to account for the impact of concurrent tobacco use on negative cannabis consequences; Fairman, 2015).

Post hoc. For models finding significant within-person effects of alcohol or cannabis sleep aid use on respective outcomes, post-hoc analyses were conducted to further investigate the observed temporal carryover process. These models were tested in the reverse direction (e.g., the effect of within-person daily daytime fatigue on next-day sleep aid use) with all of the same

covariates included. Maximum likelihood estimation with robust standard errors was used to accommodate missing data and account for negative binomial distribution of discrete outcomes in *Mplus* (Muthén et al., 2012).

Effect sizes. Global effect sizes for multilevel modelling analyses that estimate residual error variance of the full model are less straightforward than common metrics for generalized linear models (e.g., Cohen's *d* or R^2; Peugh, 2010). Thus, proportion reduction in variance was calculated as a measure of local effect size (Raudenbush & Bryk, 2002; Singer & Willett, 2003). Within-person (level 1) intercept variance from models with and without sleep aid use predictors (but all the same covariates) was compared; specifically, the difference in within-person (level 1) intercept variance of each of these models was calculated and divided by the within-person (level 1) intercept variance of the latter.

Power analysis. *A priori* power analyses for multilevel models were conducted using Power in Two Levels (PINT; Bosker, Snijders, & Guldemond, 1996; Snijders & Bosker, 1993), a program designed to estimate the standard errors of regression coefficients in hierarchical linear models for power calculations. Out of the six outcomes, the model predicting negative alcohol consequences required the largest sample size and is therefore reported herein. Based on a past study examining the impact of sleep aid use on subsequent negative alcohol consequences (Goodhines et al., 2017), it was estimated that the constructed model would account for approximately 30% of the variance in the outcome of interest (i.e., negative alcohol consequences). Required sample size for a threshold power of .80 and small effect size of .10 was calculated using covariance matrices estimated from comparable variables in an existing dataset collected from Syracuse University undergraduate students (Gellis et al., 2014; Park et al., 2014). With the number of days set at 14, the recommended sample size was 40 participants.

Ancillary Analyses

Two sets of ancillary analyses were conducted to examine replicability of the main results. First, in order to investigate the influence of other psychosocial variables which might have contributed to daily variation in sleep-aid use effects, all multilevel models were rerun as follows: (a) controlling for daily stress and poor stress tolerance separately rather than daily negative affect; (b) additionally controlling for daily health symptoms. Second, multilevel models were rerun restricting the sample to participants that endorsed that substance use for sleep aid at baseline (i.e., n = 32 alcohol sleep aid users and n = 68 cannabis sleep aid users), rather than the combined sample of all sleep aid users (n = 83).

Results

Descriptive Analyses

Means (and standard deviations) or proportions for all baseline variables are presented in the first column of Table 1. At baseline, 85% of students reported poor global sleep quality (M = 7.28; SD = 2.67) according to a standardized threshold (Buysse et al., 1989) and students reported an average of approximately 7 hours per night. On average at baseline, participants reported drinking once per week, 5 – 6 drinks per occasion during the past month and reported using cannabis 2 – 3 times during the past month. At baseline, 38% (n = 83) had used either alcohol and/or cannabis for sleep aid one or more times during the past month.

Means (and standard deviations) or proportions for all daily variables are presented in the first column of Table 1. Regarding daily data for the full sample (i.e., N = 217), 2,954 observations were obtained due to 93 missing daily surveys (i.e., 97% completion rate). On average across the 14-day assessment period, participants reported sleeping approximately 7.5 hours per night, consuming one alcoholic beverage per day, and using cannabis about once every

three days. Among past-month sleep aid users (n = 83), 1% reported alcohol sleep aid use at least once (observed range: 0 – 3 nights out of 14; median = 1 night) and 10% reported cannabis sleep aid use at least once (range: 0 – 13 nights out of 14; median = 6 nights).

The last column of Table 1 presents results from independent-sample t-tests and χ^2 tests to compare sleep aid users (n = 83) versus non-sleep aid users (n = 134) across both baseline and daily variables. At baseline, sleep aid users reported significantly higher negative mood, poor sleep quality, alcohol and cannabis frequency, and negative alcohol and cannabis consequences compared to non-users. Further, at baseline, sleep aid users reported significantly lower sleep duration and weekly frequency of waking after sleep onset compared to non-users. During the 14-day study period, sleep aid users reported significantly higher negative affect, poor sleep quality, alcohol and cannabis use, and negative alcohol and cannabis consequences compared to non-users.

Bivariate correlation coefficients for all baseline and average daily variables among the full sample (N = 217) are presented in Table 2. Significant associations were observed for baseline past-month alcohol sleep aid use with increased negative mood, decreased frequency of problems waking after sleep onset, and increased alcohol use and negative alcohol consequences at baseline. Significant associations were also observed for daily alcohol sleep aid use with increased negative affect, decreased sleep duration, increased daytime fatigue, increased alcohol use, and increased negative alcohol and cannabis consequences. Significant associations were observed for baseline past-month cannabis sleep aid use with increased negative mood, increased poor sleep quality, decreased sleep duration, increased daytime fatigue, alcohol and cannabis use, and negative alcohol and cannabis consequences at baseline. Significant associations were

observed for daily cannabis sleep aid use with increased negative affect, increased alcohol and cannabis use, and increased negative alcohol and cannabis use consequences.

Multilevel Analyses

First, using results from unconditional models, ICCs were calculated for daily poor sleep quality rating (ICC = .14), sleep duration (ICC = .14), wake-time after sleep onset (ICC = .19), daytime fatigue (ICC = .26), negative alcohol consequences (ICC = .04), and negative cannabis consequences (ICC = .41) outcomes. Evidence for within-person variability in all outcomes across the 14-day study period justified the use of multilevel modeling/nested analysis. Notably, negative alcohol consequences demonstrated highly variable responses within individuals, as evidenced by less between-person variability compared to other models; this is possibly due to the context-dependent nature of negative drinking consequences among college students (see Lee et al., 2017). Results are presented below separately for alcohol sleep aid (Table 3) and cannabis sleep aid (Table 4) predicting sleep- and substance-related outcomes.

Alcohol sleep aid.

Poor sleep quality rating. As shown in Table 3, column 1, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that alcohol sleep aid use was not significantly associated with daily poor sleep quality rating on average ($\gamma = -0.97$, $p = .54$) after accounting for covariates. Within-person (level 1) findings suggest that daily alcohol sleep aid use was not significantly associated with poor sleep quality on either the same night ($\gamma = 0.65$, $p = .09$) or the following night ($\gamma = 0.03$, $p = .93$) after accounting for covariates. That is, individual students' poor sleep quality ratings were not significantly different on either alcohol sleep aid-using nights or the following night, as compared to individual averages. Regarding covariates, between-person findings suggest that students with greater negative affect were more

likely to report poorer daily subjective sleep quality on average; within-person findings suggest that weekdays (versus weekends), negative affect, and daily alcohol quantity were associated with poorer subjective sleep quality on the same day (*p*'s < .05).

Sleep duration. As shown in Table 3, column 2, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that alcohol sleep aid use was not significantly associated with daily sleep duration on average ($\gamma = 1.76$, $p = .59$) after accounting for covariates. Within-person (level 1) findings suggest that daily alcohol sleep aid use was not significantly associated with sleep duration on either the same night ($\gamma = -0.11$, $p = .90$) or the following night ($\gamma = 0.24$, $p = .76$) after accounting for covariates. That is, individual students' sleep duration was not significantly different on either alcohol sleep aid-using nights or the following night, as compared to individual averages. Regarding covariates, between-person findings suggest that female students and students with lower negative affect were more likely to report longer daily sleep duration on average; within-person findings suggest that greater daily alcohol quantity was associated with shorter sleep duration on the same day (*p*'s < .05).

Wake-time after sleep onset. As seen in Table 3, column 3, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that alcohol sleep aid use was not significantly associated with daily wake-time after sleep onset on average ($\gamma = -14.74$, $p = .81$) after accounting for covariates. Within-person (level 1) findings suggest that daily alcohol sleep aid use was not significantly associated with wake-time after sleep onset on either the same night ($\gamma = -3.38$, $p = .80$) or the following night ($\gamma = 0.30$, $p = .98$) after accounting for covariates. That is, individual students' wake-time after sleep onset was not significantly different on either alcohol sleep aid-using nights or the following night, as compared to individual average. No

between- or within-person covariates included in the model were significantly associated with daily wake-time after sleep onset (*p*'s > .05).

Daytime fatigue. As seen in Table 3, column 4, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that alcohol sleep aid use was not significantly associated with daily daytime fatigue on average ($\gamma = 0.47$, $p = 84$) after accounting for covariates. Within-person (level 1) findings suggest that daily alcohol sleep aid use was not significantly associated with higher daytime fatigue either the following day ($\gamma = 0.62$, $p = .15$) or the day after that ($\gamma = -0.28$, $p = .49$) after accounting for covariates. That is, individual students' daytime fatigue was not significantly different following alcohol sleep aid-using nights, compared to individual average. Regarding covariates, between-person findings suggest that students with higher negative affect were more likely to report higher daily daytime fatigue on average; within-person findings suggest that daytime fatigue decreased over the 14 study days within individuals and alcohol quantity was associated with greater daytime fatigue two days following (*p*'s < .05).

Negative alcohol consequences. As seen in Table 3, column 5, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that alcohol sleep aid use was not associated with negative alcohol consequences on average (IRR = 0.06, 95% CI [-0.33, 0.46], $p = .47$) after accounting for covariates. Within-person (level 1) findings suggest that alcohol daily sleep aid use was not significantly associated with negative alcohol consequences on either the following day (IRR = 2.05, 95% CI [-0.60, 4.70], $p = .36$) or the day after that (IRR = 0.48, 95% CI [-0.08, 1.04], $p = .30$) after accounting for covariates. That is, individual students' experiences of negative alcohol consequences were not significantly different following alcohol sleep aid-using nights, compared to individual average. Regarding covariates, between-person findings

suggest that students who reported higher alcohol quantity and higher negative affect were more likely to experience more daily negative alcohol consequences on average; within-person findings suggest that weekends (versus weekdays) and were associated with more negative alcohol consequences than usual and previous-day alcohol quantity was associated with decreased next-day negative alcohol consequences (*p*'s < .01).

Cannabis sleep aid.

Poor sleep quality rating. As shown in Table 4, column 1, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that cannabis sleep aid use was not significantly associated with daily poor sleep quality rating on average (γ = -0.46, p = .14) after accounting for covariates. Within-person (level 1) findings suggest that daily cannabis sleep aid use was not significantly associated with poor sleep quality on either the same night (γ = -0.06, p = .69) or the following night (γ = 0.04, p = .76) after accounting for covariates. That is, individual students' poor sleep quality ratings were not significantly different on either cannabis sleep aid-using nights or the following night, as compared to individual averages. Regarding covariates, between-person findings suggest that students with greater negative affect were more likely to report poorer daily subjective sleep quality on average; within-person findings suggest negative affect was associated with poorer subjective sleep quality on the same day (*p*'s < .05).

Sleep duration. As shown in Table 4, column 2, consistent with *a priori* hypotheses, between-person (level 2) findings indicate that cannabis sleep aid use was significantly associated with longer sleep duration on average (γ = 1.48, p = .02) after accounting for covariates. Within-person (level 1) findings suggest that daily cannabis sleep aid use was significantly associated with greater sleep duration the same night (γ = 0.62, p = .04), but not the following night (γ = -0.08, p = .78), after accounting for covariates. That is, individual students'

sleep duration was significantly longer on cannabis sleep aid-using nights, as compared to individual averages. Regarding covariates, between-person findings suggest that female students and students with lower negative affect were more likely to report longer daily sleep duration on average; within-person findings suggest previous-day tobacco use was associated with shorter sleep duration (p's < .05).

In order to further investigate the observed temporal carryover effects of cannabis sleep aid use on same-night sleep duration within individuals, this model was subsequently tested in the reverse direction (i.e., the effect of within-person daily sleep duration on next-day cannabis sleep aid use). Within-person findings indicate that neither previous-day nor lagged sleep duration was associated with the likelihood that students would utilize cannabis for sleep aid (IRR = 1.05, 95% CI [0.98, 1.11], p = .28; IRR = 1.03, 95% CI [0.94, 1.11], p = .62) after accounting for covariates. Thus, within-person findings indicate that cannabis sleep aid use was significantly associated with longer same-night sleep duration, but not vice versa.

Wake-time after sleep onset. As seen in Table 4, column 3, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that cannabis sleep aid use was not significantly associated with daily wake-time after sleep onset on average (γ = -8.89, p = .47) after accounting for covariates. Consistent with *a priori* hypotheses, within-person (level 1) findings suggest that daily cannabis sleep aid use was significantly associated with decreased wake-time after sleep onset on the same night (γ = -13.27, p = .004), but not the following night (γ = 4.06, p = .37), after accounting for covariates. That is, individual students' wake-time after sleep onset was significantly shorter on cannabis sleep aid-using nights, as compared to individual average. No between- or within-person covariates included in the model were significantly associated with daily wake-time after sleep onset (p's > .05).

In order to further investigate the observed temporal carryover effects of cannabis sleep aid use on same-night wake-time after sleep onset within individuals, this model was subsequently tested in the reverse direction (i.e., the effect of within-person daily wake-time after sleep onset on next-day cannabis sleep aid use). Within-person findings indicate that neither previous-day nor lagged wake-time after sleep onset changed the likelihood that students would utilize cannabis for sleep aid (IRR = 1.00, 95% CI [0.98, 1.01], p = .77; IRR = 0.99, 95% CI [0.97, 1.00], p = .18) after accounting for covariates. Thus, within-person findings indicate that cannabis sleep aid use was significantly associated with shorter same-night wake-time after sleep onset, but not vice versa.

Daytime fatigue. As seen in Table 4, column 4, inconsistent with *a priori* hypotheses, between-person (level 2) findings indicate that cannabis sleep aid use was not significantly associated with daily daytime fatigue on average (γ = 0.56, p = .22) after accounting for covariates. Consistent with *a priori* hypotheses, within-person (level 1) findings suggest that daily cannabis sleep aid use was significantly associated with higher daytime fatigue the following day (γ = 0.34, p = .04), but not the day after that (γ = -0.07, p = .69), after accounting for covariates. That is, individual students' daytime fatigue was significantly higher following cannabis sleep aid-using nights, as compared to individual average. Regarding covariates, between-person findings suggest that students with higher negative affect were more likely to report higher daily daytime fatigue on average; within-person findings suggest that daytime fatigue decreased over the 14 study days within individuals (p's < .01).

In order to further investigate the observed temporal carryover effects of cannabis sleep aid use on next-day daytime fatigue within individuals, this model was subsequently tested in the reverse direction (i.e., the effect of within-person daily daytime fatigue on same-day cannabis

sleep aid use). Within-person findings indicate that neither same- nor previous-day daytime fatigue increased the likelihood that students would utilize cannabis for sleep aid (IRR = 0.96, 95% CI [0.79, 1.13], p = .68; IRR = 1.00, 95% CI [0.88, 1.12], p = .98) after accounting for covariates. Thus, within-person findings indicate that cannabis sleep aid use was significantly associated with higher next-day daytime fatigue, but not vice versa.

Negative cannabis consequences. As seen in Table 4, column 5, consistent with *a priori* hypotheses, between-person (level 2) findings indicate that cannabis sleep aid use was significantly associated with greater number of daily negative cannabis consequences on average (IRR = 18.87, 95% CI [-20.40, 58.14], p = .02) after accounting for covariates. Inconsistent with *a priori* hypotheses, within-person (level 1) findings suggest that daily cannabis sleep aid use was not significantly associated with negative cannabis consequences experienced on either the following day (IRR = 1.34, 95% CI [0.71, 1.97], p = .31) or the day after that (IRR = 0.81, 95% CI [0.47, 1.15], p = .40) after accounting for covariates. That is, individual students' experiences of negative cannabis consequences were not significantly different following cannabis sleep aid-using nights, compared to individual average. Regarding covariates, between-person findings suggest that male students were more likely to experience more daily negative cannabis consequences on average; within-person findings suggest that negative cannabis consequences decreased over the 14 study days within individuals and previous-day cannabis frequency was significantly associated with increased next-day negative cannabis consequences (p's < .05).

Effect sizes in multilevel models. Regarding proportion reduction in variance as a measure of local effect size, overall results indicate that both alcohol and cannabis sleep aid use independently account for a small reduction in variance for all sleep- and substance-related outcomes, with one exception (i.e., alcohol sleep aid use effects on daily sleep duration).

Specifically, after adding alcohol sleep aid predictors to the models, within-person (level 1) intercept variance decreased by 0.4% for daily poor sleep quality rating, by 0.1% for daily wake-time after sleep onset, by 0.4% for daily daytime fatigue, and by .03% for negative alcohol consequences; within-person (level 1) intercept variance increased by 0.02% for daily sleep duration. After adding cannabis sleep aid predictors to the models, within-person (level 1) intercept variance decreased by 0.1% for daily poor sleep quality rating, by 0.04% for daily sleep duration, by 7% for daily wake-time after sleep onset, by 0.4% for daily daytime fatigue, and by 1% for negative cannabis consequences.

Ancillary Analyses

First, replicated multilevel models controlling for other psychosocial covariates (i.e., stress, poor stress tolerance, and health symptoms) yielded results largely consistent with primary analyses in terms of the significant between- and within-person sleep aid effects. Results for alcohol sleep aid use differed from main results such that, after additionally controlling for daily health symptoms, the within-person effect of alcohol sleep aid on next-day negative drinking consequences became significant (IRR = 3.37, 95% CI [0.03 , 6.71], p = .04). Results for cannabis sleep aid use differed from main results as follows: (a) after controlling for stress, the between-person effect of cannabis sleep aid on same-night sleep quality became significant (γ = -0.64, p = .04), but the within-person effect of cannabis sleep aid on same-night sleep duration (γ = 0.59, p = .05) and the between-person effect for negative cannabis consequences (IRR = 12.60, 95% CI [-15.45, 40.64], p = .06) became only marginally significant; (b) after controlling for stress tolerance, the between-person effect of cannabis sleep aid on same-night sleep quality became significant (γ = -0.75, p = .02), but the between-person effect for negative cannabis consequences was no longer significant (IRR = 6.93, 95% CI [-6.03, 19.88], p = .09);

(c) after additionally controlling for daily health symptoms, the between-person effect for negative cannabis consequences was no longer significant (IRR = 7.54, 95% CI [-7.78, 22.86], p = .10).

Second, replicated multilevel models using subsamples restricted to participants that endorsed that substance used for sleep aid at baseline (i.e., *n* = 32 alcohol sleep aid users and *n* = 68 cannabis sleep aid users), rather than the combined sample of all sleep aid users (*n* = 83), yielded patterns of significance largely consistent with main analyses. The only deviation from main results is that, after selecting only past-month cannabis sleep aid users, the within-person effect of daily cannabis sleep aid use on same-night sleep duration was no longer significant (γ = 0.33, *p* = .29).

Discussion

A growing empirical literature indicates prevalent alcohol and cannabis use to help sleep among college students, yet little is known about potential adverse proximal sleep- and substance-related outcomes. The current daily diary study of college alcohol and cannabis users examined whether alcohol or cannabis sleep aid use resulted in changes in subsequent sleep and associated functioning (i.e., subjective sleep quality rating, sleep duration, wake-time after sleep onset, and daytime fatigue) and negative alcohol and cannabis use consequences both between- and within-individuals in daily life. By investigating sleep aid use and its proximal outcomes as they occurred naturally in daily college life, this study design allowed for examination of unique within-person variability separate from known between-person associations. Consistent with study hypotheses, between-person results indicate that cannabis sleep aid use, independent of cannabis use frequency, was associated with longer sleep duration and more negative cannabis consequences on average across 14 days. Also, within-person results indicate that cannabis sleep

aid use, independent of daily cannabis use frequency, was associated with longer same-night sleep duration and reduced same-night wake-time after sleep onset, but also higher next-day daytime fatigue, compared to individual averages. However, inconsistent with study hypotheses, results indicate that alcohol sleep aid use was not associated with any between-person or within-person change in same-night sleep, next-day fatigue, or next-day alcohol consequences; null findings may be due to the low observed frequency of alcohol sleep aid use over 14 days (1%) among the current sample. Overall, these novel daily findings suggest that cannabis sleep aid use, but not alcohol sleep aid use, may improve same-night sleep duration and maintenance within college students, yet does not improve subjective sleep quality and actually has the unintended result of significantly higher next-day fatigue the following day as well as greater negative cannabis consequences on average.

Alcohol Sleep Aid

Because only 1% of daily observations include a positive endorsement of alcohol sleep aid use, the following results must be interpreted with caution due to potentially under-powered analyses. Results of ancillary analyses restricted to the 32 participants endorsing alcohol sleep aid use at baseline are consistent with main analyses.

Sleep-related outcomes. Inconsistent with earlier experimental evidence for the association of alcohol use with improved subjective sleep quality (Roehrs et al., 1996), individual students' sleep quality ratings were no different from their personal averages on alcohol sleep-aid using nights after controlling for daily alcohol quantity in the current study. Further, inconsistent with experimental evidence for the association of alcohol use with decreased sleep duration (Arnedt et al., 2011), increased wake-time during the night (Arnedt et al., 2011; Roehrs et al., 1991; Williams et al., 1983), and greater fatigue the following day (Chait

et al., 1994), individual students' same-night sleep and next-day fatigue ratings were no different from their personal averages on alcohol sleep-aid using nights after controlling for daily alcohol quantity in the current study. Likewise, no between-person effects were observed for associations of alcohol sleep aid use with sleep-related outcomes, after controlling for daily alcohol quantity. Taken collectively, findings indicate that alcohol sleep aid use neither protects against nor increases risk for same-night sleep problems or next-day fatigue, after accounting for daily alcohol quantity.

It is possible that inconsistency with previous experimental findings is due to important methodological differences, specifically the current study's novel consideration of alcohol sleep aid. Unlike previous experimental investigations of the effects of alcohol administration on sleep, the current daily-level study separated out the effects of alcohol sleep aid use after controlling for daily alcohol quantity. Thus, null results indicate that alcohol sleep aid use was not associated with subjective sleep parameters or negative drinking consequences over and above daily alcohol quantity. Rather, results indicate that greater alcohol quantity across 14 days was significantly associated with more negative drinking consequences on average; further, greater daily alcohol quantity was associated with poorer same-night subjective sleep quality, decreased same-night sleep duration, and surprisingly decreased next-day negative drinking consequences within individuals (p's $< .05$; see Table 3). The negative association between daily alcohol quantity and next-day negative drinking consequences might be explained by the fact that students did not drink heavily multiple days in a row in the current sample and therefore did not experience consequences the day following a heavier drinking day. Studies of more heavy-drinking college samples might yield different results. Future research with more heavily-using alcohol sleep aid users is needed to replicate these findings that alcohol sleep aid use neither improves nor

worsens subsequent subjective sleep and fatigue within college students after controlling for other alcohol consumption.

Substance-related outcomes. Inconsistent with a recent study indicating an average association between alcohol sleep aid use and increased negative alcohol consequences over a 2-month period (Goodhines et al., 2017), alcohol sleep aid use was not associated with negative drinking consequences on average after accounting for daily alcohol quantity in the current study. Further, individual students' negative alcohol consequences were not significantly different from their personal averages on nights when they used alcohol for sleep aid. The current study's non-significant within-person effects may have been influenced by a floor effect in the negative alcohol consequence outcome (possible range = 0 – 22; $M = 0.27$; $SD = 0.29$ for sleep aid users), precluding detection of within-person variability in day-to-day negative alcohol consequences across study days. Further, it is possible that the association between sleep aid use and negative drinking consequences develops within sleep aid users over a longer period of time, outside the scope of a daily-level investigation. However, results of ancillary analyses additionally controlling for between- and within-person daily health symptoms indicate that students experienced significantly more negative alcohol consequences than their personal average on days immediately following alcohol sleep aid-using nights. Indeed, the observed positive association between daily health symptoms and daily negative cannabis consequences ($p < .05$; see Table 2) suggests that individual variability in negative cannabis consequences may be closely related to state of physical health. To more accurately and comprehensively capture these relationships, future researchers should consider assessing within-person variation in daily negative alcohol consequences among a larger sample of alcohol sleep aid users across a longer timeframe, as well as assessing potential psychosocial moderators (e.g., health).

Cannabis Sleep Aid

Sleep-related outcomes. Inconsistent with earlier experimental evidence for the average association of cannabis sleep aid use with greater sleep satisfaction (Bedi et al., 2010; Haney et al., 2007), cannabis sleep aid use was not associated with same-night sleep quality rating on average in the current study, nor were individual students' subjective sleep quality ratings different from their personal averages on cannabis sleep-aid using nights, after accounting for daily cannabis frequency. Regarding within-person variability, cannabis sleep aid use may not improve subjective sleep quality relative to the individual average (as hypothesized); rather, cannabis sleep aid use may prevent sleep quality from dipping below the individual average, thereby resulting in minimized within-person variability across days. Alternatively, dosage, administration, and timing of cannabis sleep aid use (e.g., four inhalations or "puffs" from a "marijuana cigarette" at 9:00pm; Chait et al., 1994) in previous experimental designs might not accurately reflect self-initiated sleep aid use by college students. Thus, cannabis sleep aid use naturally occurring among college students may have unique effects on subjective sleep quality that is not captured by experimental procedures. Future studies may consider assessing the potential moderating effect of dosage on the relationship between cannabis sleep aid use and same-night sleep quality rating, as well as updating experimental findings with self-selection of cannabis administration method and dosage among larger samples of modern college students for maximized ecological validity.

Consistent with earlier experimental evidence for the association of cannabis sleep aid use with extended total sleep time (Feinberg et al., 1975; Tassinari et al., 1999), cannabis sleep aid use was associated with greater sleep duration on average in the current study and individual students' sleep duration was longer than their personal averages on cannabis sleep-aid using

nights, after accounting for daily cannabis use frequency. Further, although the current study found that cannabis sleep aid use was not associated with wake-time after sleep onset on average, individual students' wake-time after sleep onset was significantly shorter than their personal averages on cannabis sleep-aid using nights, consistent with between-person experimental findings (Feinberg et al., 1975; Tassinari et al., 1999). The latter findings suggest that previous between-person findings might be better explained by within-person variability in wake-time subsequent to cannabis sleep aid use, as observed when these between- and within-person effects were disaggregated in the current study.

Lastly, as hypothesized, results support a directional effect of cannabis sleep aid use on next-day fatigue after accounting for daily cannabis use frequency, such that individual students' daytime fatigue was higher than their personal average on days when they used alcohol and/or cannabis for sleep aid the night before. This finding is consistent with evidence that, on average, cannabis use is associated with increased next-day fatigue (Chait et al., 1985) due to the slow elimination of THC. However, between-person findings were insignificant, again suggesting that previous between-person findings might be better explained by within-person variability in daytime fatigue subsequent to cannabis sleep aid use.

Taken collectively, results indicate that cannabis sleep aid use may function to improve same-night sleep duration and maintenance, but does not improve subjective sleep quality and actually increases fatigue the following day among college students. The mechanism underlying these seemingly conflicting findings may involve predictable changes in sleep architecture following cannabis use (for a review, see Garcia et al., 2015; Schierenbeck et al., 2008). Pre-sleep cannabis administration induces sleep onset (Karacan et al., 1976; Pranikoff et al., 1973) and enhances slow wave sleep (Barratt, Beaver, & White, 1974; Freemon, 1982) throughout the

night, but also decreases REM sleep and REM density (Feinberg et al., 1975; Tassinari et al., 1999). Thus, while sleep maintenance is improved, sleep obtained is actually less restorative than typical sleep, likely resulting in increased next-day fatigue. While concurrent objective assessment of sleep parameters (e.g., polysomnography) was outside of the scope of the current study, future studies should consider simultaneously assessing sleep architecture and staging using ambulatory assessment methods to further investigate mechanisms underlying associations between cannabis sleep aid use and behavioral sleep-related outcomes.

Substance-related outcomes. Consistent with Brower's theory (2001, 2003) that sleep aid use leads to increased substance use and problems over time, the current study found that cannabis sleep aid use was associated with more negative cannabis consequences on average after accounting for daily cannabis frequency. This finding is novel to our limited understanding of cannabis sleep aid use. Notably, results of ancillary analyses separately controlling for other psychosocial factors (i.e., health symptoms, stress, and stress intolerance) found that the average effect of daily cannabis use on negative drinking consequences was not significant. Discrepancy between main analyses controlling for daily negative affect and ancillary analyses highlight the important role of negative affect in the daily experience of negative cannabis use consequences. Future researchers should continue to account for negative affect when investigating associations between cannabis sleep aid use and negative cannabis consequences, as well as consider assessment of other relevant psychosocial moderators of this relationship.

Further, the inconsistent finding that individual students' negative cannabis consequences were not significantly different from their personal averages on nights when they used cannabis for sleep aid after accounting for daily cannabis frequency is also novel to empirical literature. Null within-person findings might be explained by the short-term daily timeframe of the current

study, as hypothesized changes in negative cannabis consequences might occur over a longer period of time outside the scope of the current study. Mixed findings regarding negative cannabis consequences remain promising and warrant continued investigation among college cannabis users. Future research assessing within-person variation among a larger sample of cannabis sleep aid users across a longer timeframe is needed to elucidate individual trajectories and longer-term substance-related outcomes of cannabis sleep aid use.

Clinical Implications

Results of the current study have the potential to inform clinical intervention efforts. By highlighting potential adverse proximal outcomes resulting from sleep aid use, findings support the promotion of healthy sleep behaviors among college alcohol and cannabis users. Psychological interventions which have demonstrated the strongest and most consistent evidence for improving sleep among college students include cognitive-behavioral therapy and sleep hygiene interventions (for a review, see Friedrich & Schlarb, 2017). Regarding college sleep health interventions, findings support the additional evaluation of sleep-related functional impairment (e.g., residual daytime fatigue). For example, cognitive therapy for insomnia includes monitoring of next-day functioning (Harvey, 2005). College students endorse high rates of sleep-related functional impairment (e.g., drowsiness, falling asleep in class; DeMartini et al., 2014; Oginska & Pokorski, 2006), indicating that this is a prevalent problem worthy of direct assessment and intervention. Also, endorsement of alcohol and/or cannabis sleep aid use in college healthcare settings may present a “teachable moment” (Lawson & Flocke, 2009) and an opportunity for providers to identify observed outcomes, discuss sleep problems, and increase motivation for the development of more adaptive coping strategies. This behavior change intervention might alternatively be achieved by expanding the substance-specific content already

present within existing sleep health interventions (Fucito et al., 2015); for example, limiting alcohol use before bed is recommended as a standard component of sleep hygiene education (Stepanski & Wyatt, 2003).

Strengths and Limitations

This study benefitted from its ecologically valid design and powerful within-person analysis providing directional modeling of day-to-day responses. By repeatedly sampling participant responses in daily life within their natural environment, findings are more directly generalizable to the daily lives of college students compared to experimental, cross-sectional, and multi-wave longitudinal designs. Further, while the current findings cannot claim causality due to the observational nature of the study design, the statistical modeling of relationships observed within a naturally-occurring temporal sequence does allow for identification of directional effects across days. It is also important to highlight that the current results include within-person findings, such that each individual served as their own reference point for the purposes of analysis. By disaggregating within-person fluctuations around an individual's average, we are able to eliminate the potential confound that sample-level trends were responsible for the processes observed. This within-person analysis constitutes a major incremental contribution to limited literature in this area.

Notwithstanding novel and significant contributions to the literature, limitations of the current study must be considered. First, data were drawn from a predominantly white, female sample of students enrolled in a northeastern private university. Because drinking and sleep patterns vary by individual and school characteristics (Johnston et al., 2015; Lichstein et al., 2004), replication in samples with greater demographic heterogeneity is warranted to investigate generalizability of the current results to the larger college student population. Further, study

eligibility criteria required that all participants endorse alcohol and/or cannabis use at least once in the past 30 days, thus findings might not generalize to students who use alcohol/cannabis very infrequently; however, in comparable samples of predominantly White college students, approximately 83% endorsed alcohol use (Lowery, Merrill, & Carey, 2018) and 83% endorsed cannabis use (Tzilos et al., 2014) in the past 30 days, suggesting this sampling bias may not be substantial. Similarly, findings might not generalize to clinical samples of young adults, as the majority of the current sample were low-risk recreational users (i.e., 81% did not screen positive for alcohol or cannabis use disorder). Additionally, subjective assessments may have been vulnerable to self-reporting errors, such as under- or over-reporting of substance use due to social desirability bias; however, web-based self-reports of personal alcohol use have demonstrated validity among college students (Kypri et al., 2016). Intoxication at night before bed might also have biased reporting the following morning due to memory issues (e.g., blackouts) and thus future studies should utilize biological markers (e.g., urine toxicology, ethyl glucuronide) to assess whether level of intoxication influences effects observed. Observation of target daily relationships was potentially limited by the 14-day timeframe of the current study; although recommended by the literature (Buysse et al., 2006; Gunthert et al., 2012), this timeframe is likely too brief to optimally capture the phenomena of alcohol sleep aid use in college students. Lastly, given the observational nature of the current design, it is impossible to know what might have happened in the case of non-sleep aid use (i.e., the counterfactual; for a review, see Collins, Hall, & Paul, 2004); however, this limitation is mitigated by the fact that variation is observed around each participant's personal average and therefore participants serve as their own personal reference.

Future Directions

Results of the current study have the potential to inform future research. Future investigations might consider extending the duration of the assessment period in order to maximally capture observation of this phenomena. For the same reason, future researchers might also consider specifically recruiting participants who endorse regular sleep aid use and assessing the potential moderating effect of dosage on the relationship between sleep aid use and proximal outcomes. In order to elucidate amount of cannabis being used and investigate dosage-specific effects, future studies should assess event-level quantity of cannabis use in addition to daily frequency. This might be achieved by asking participants to report quantity in grams, dollar amounts, or length of time to consume a purchased amount (as recommended by Prince et al., 2018). While all of these methods have limitations and are vulnerable to misreporting, legalization and increased regulation of cannabis use might engender improved standardization moving forward. Results may also be replicated utilizing objective assessments of sleep and substance use (e.g., wrist-worn actigraphy and BAC-tracker technology), providing converging evidence for subjective reports.

Moving forward, the current demonstration of associated consequences provides justification and rationale for continued investigation into associated risk and protective factors associated with sleep aid use. Potential daily antecedents indicated by the literature include sleep problems (e.g., sleep duration, waking after sleep onset, sleep efficiency), negative affect, stress, and stress intolerance (Lund et al., 2010; Stasio et al., 2008). Identification of such factors might allow for improved identification of at-risk students, thereby potentially optimizing targeted prevention and intervention efforts. Notably, research on the mechanisms underlying the decision to use sleep aid is lacking; thus, exploratory qualitative data is needed to identify potential mediators and moderators of this decision-making process (e.g., expectancies, past

experiences, peer norms; Maisto et al., 1999). Lastly, clinical research is needed to investigate optimal intervention strategies (e.g., integration of sleep and substance use treatments) tailored specifically for college students using substances for sleep aid.

Conclusion

Results of the present daily diary study indicate that cannabis sleep aid use, independent of daily cannabis use frequency, was associated with longer same-night sleep duration and reduced wake-time after sleep onset, but also higher next-day daytime fatigue compared to individual averages; however, inconsistent with study hypotheses, results indicate that alcohol sleep aid use was not associated with any within-person change in same-night sleep, next-day fatigue, or next-day alcohol consequences. The current findings offer mixed support for application of Brower's theory (2001, 2003) to college alcohol and cannabis sleep aid use, thereby adding to the paucity of knowledge on the adverse short-term effects of sleep aid use. Continued research is needed to further capture and clarify the impact of alcohol and cannabis sleep aid use on sleep- and substance-related consequences in daily college life.

Table 1
Means or Percentages of Study Variables as a Function of Past-Month Sleep Aid Use Reported at Baseline

	All Participants (N = 217)	Sleep Aid Users (n = 83)	Non-Sleep Aid Users (n = 134)	Group Comparison between Sleep Aid Users vs. Non-Users
Baseline Variables (possible range)				
Demographics				
Male Sex	24%	30%	21%	$\chi^2(1) =$ 33.08***
Age	19.38 (1.17)	19.33 (1.11)	19.40 (1.21)	$t(202) =$ -1.62
Freshman	30%	34%	28%	$\chi^2(1) =$ 11.90***
White Race	73%	72%	73%	$\chi^2(1) =$ 0.34
U.S. Country of Origin	88%	89%	87%	$\chi^2(1) =$ 2.54
Full-Time Student	100%	100%	99%	$\chi^2(1) =$ 8.78**
Not Working	72%	74%	71%	$\chi^2(1) =$ 2.40
Living On Campus	74%	74%	74%	$\chi^2(1) =$ 0.06
Greek Affiliation	32%	33%	32%	$\chi^2(1) =$ 0.06
Negative Mood (0 – 12)	**3.12 (2.85)**	**3.72 (2.88)**	**2.75 (2.76)**	**$t(215) =$ 9.23*** **
Sleep				
Poor Sleep Quality Rating (0 – 3)	**1.31 (0.59)**	**1.42 (0.60)**	**1.24 (0.58)**	**$t(215) =$ 8.26*** **
Sleep Duration (Hours)	**6.80 (1.21)**	**6.69 (1.14)**	**6.87 (1.25)**	**$t(215) =$ -4.04*** **
Weekly Frequency Waking After Sleep Onset (0 – 3)	**1.59 (1.05)**	**1.53 (1.05)**	**1.63 (1.06)**	**$t(215) =$ -2.46***
Daytime Fatigue (0 – 54)	29.42 (10.57)	29.54 (9.94)	29.34 (10.94)	$t(215) =$ 0.52
Alcohol				
Past-Month Alcohol Sleep Aid Frequency (0 – 7)	**0.45 (1.22)**	**1.18 (1.74)**	**0.00 (0.00)**	**$t(215) =$ 23.17*** **
Past-Month Alcohol Frequency (0 – 7)	**3.39 (1.34)**	**3.61 (1.36)**	**3.25 (1.30)**	**$t(215) =$ 7.17*** **
Past-Month Alcohol Quantity (0 – 9)	**2.51 (1.22)**	**2.72 (1.16)**	**2.38 (1.23)**	**$t(215) =$ 7.84*** **
Negative Alcohol Consequences (0 – 48)	**10.87 (8.47)**	**13.35 (9.36)**	**9.33 (7.43)**	**$t(215) =$ 12.36*** **
Cannabis				
Past-Month Cannabis Sleep Aid Frequency (0 – 7)	**1.19 (2.11)**	**3.12 (2.37)**	**0.00 (0.00)**	**$t(215) =$ 44.93*** **
Past-Month Cannabis Frequency (0 – 7)	**2.08 (2.44)**	**3.83 (2.51)**	**1.00 (1.61)**	**$t(215) =$ 34.31*** **
Negative Cannabis Consequences (0 – 50)	**8.28 (7.74)**	**10.65 (8.04)**	**5.22 (6.01)**	**$t(215) =$ 16.23*** **
Daily Variables (possible range)				
Demographics				
Negative Affect (0 – 20)	**6.50 (3.22)**	**7.23 (3.68)**	**6.08 (2.85)**	**$t(215) =$ 9.82*** **
Stress (0 – 7)	**2.92 (1.56)**	**3.08 (1.62)**	**2.82 (1.52)**	**$t(215) =$ 4.29*** **
Poor Stress Tolerance (0 – 7)	**2.51 (1.52)**	**2.78 (1.59)**	**2.35 (1.46)**	**$t(215) =$ 7.19*** **
Health Symptom Count 0 – 10)	**1.64 (1.23)**	**1.73 (1.31)**	**1.59 (1.18)**	**$t(215) =$ 2.86** **
Sleep				
Poor Sleep Quality Rating (0 – 5)	**1.53 (0.91)**	**1.59 (0.92)**	**1.50 (0.91)**	**$t(215) =$ 2.58***
Sleep Duration (Hours)	7.55 (1.84)	7.47 (1.92)	7.59 (1.78)	$t(215) =$ -1.72
Wake-Time After Sleep Onset (Minutes)	13.95 (23.30)	14.62 (23.77)	13.57 (23.04)	$t(215) =$ 0.75
Daytime Fatigue (0 – 4)	2.59 (1.12)	2.61 (1.12)	2.58 (1.11)	$t(215) =$ 0.54
Alcohol				
Alcohol Sleep Aid (yes/no)	**0.38%**	**1%**	**0%**	**$t(215) =$ 2.10***
Alcohol Quantity	**1.10 (2.55)**	**1.49 (3.01)**	**0.88 (2.22)**	**$t(215) =$ 5.74*** **
Negative Alcohol Consequences (0 – 22)	**0.23 (0.94)**	**0.29 (0.99)**	**0.19 (0.91)**	**$t(215) =$ 2.65** **
Cannabis				
Cannabis Sleep Aid (yes/no)	**4%**	**10%**	**0%**	**$t(215) =$ 10.64*** **
Cannabis Frequency	**0.32 (0.93)**	**0.68 (1.27)**	**0.11 (0.55)**	**$t(215) =$ 13.68*** **
Negative Cannabis Consequences (0 – 14)	**0.13 (0.60)**	**0.31 (0.92)**	**0.03 (0.25)**	**$t(215) =$ 9.51*** **

Note. N = 217. Significant group differences at $p < .05$ are highlighted in bold font.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2
Bivariate Correlation Coefficients of Study Variables

		r																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Baseline Variables																											
1.	Past-Month Alcohol Sleep Aid	—																									
2.	Past-Month Cannabis Sleep Aid	**.23**	—																								
3.	Male Sex	**.08**	**.08**	—																							
4.	Negative Mood	**.09**	**.16**	**-.10**	—																						
5.	Poor Sleep Quality Rating	-.03	**.15**	**-.08**	**.26**	—																					
6.	Sleep Duration	-.03	**-.05**	**-.06**	**-.09**	**-.25**	—																				
7.	Waking After Sleep Onset	**-.04**	-.01	**-.14**	**.21**	**.17**	**.05**	—																			
8.	Daytime Fatigue	.00	**.05**	**-.10**	**.28**	**.20**	-.00	**.21**	—																		
9.	Past-Month Alcohol Frequency	**.07**	**.19**	**.14**	**-.09**	**-.09**	.00	**-.08**	**-.11**	—																	
10.	Past-Month Alcohol Quantity	**.06**	**.19**	**.24**	**-.18**	-.02	.00	**-.05**	**-.13**	**.52**	—																
11.	Negative Alcohol Consequences	**.07**	**.27**	.03	**.13**	**.08**	-.01	.02	**.22**	**.43**	**.38**	—															
12.	Past-Month Cannabis Frequency	.02	**.70**	**.14**	**.08**	**.04**	**-.15**	-.01	**-.07**	**.22**	**.18**	**.25**	—														
13.	Negative Cannabis Consequences	-.01	**.43**	**.24**	**.22**	**.07**	**-.12**	.01	**.26**	**-.09**	**.14**	**.30**	**.57**	—													
Daily Variables																											
14.	Alcohol Sleep Aid	**.07**	.03	.01	**.05**	.01	-.03	**.04**	**.06**	**.04**	.02	.01	.01	-.01	—												
15.	Cannabis Sleep Aid	.01	**.28**	-.01	**.08**	**.07**	**-.04**	**.05**	**.06**	.02	.03	**.07**	**.26**	**.22**	.02	—											
16.	Negative Affect	**.10**	**.13**	**-.06**	**.48**	**.14**	**-.06**	**.07**	**.16**	**-.07**	**-.06**	**.17**	**.07**	**.23**	.03	**.05**	—										
17.	Stress	**.05**	**.06**	**-.07**	**.24**	**.14**	**-.07**	**.05**	**.12**	-.01	.01	**.14**	.03	**.12**	.00	**.05**	**.50**	—									
18.	Poor Stress Tolerance	**.09**	**.12**	.01	**.21**	**.15**	**-.06**	.03	**.15**	-.00	**.08**	**.16**	**.04**	**.14**	.01	**.08**	**.44**	**.61**	—								
19.	Health Symptom Count	-.02	**.05**	**-.07**	**.18**	**.18**	.00	**.04**	**.07**	**.04**	.03	**.11**	**.09**	**.15**	.02	**.11**	**.24**	**.17**	**.15**	—							
20.	Poor Sleep Quality Rating	.02	.03	**-.05**	**.06**	**.23**	-.01	**.05**	**.10**	-.02	.01	**.10**	**-.04**	.02	.02	-.02	**.16**	**.18**	**.17**	**.11**	—						
21.	Sleep Duration	**-.04**	.02	**-.05**	**-.04**	**-.11**	**.25**	**.06**	.03	-.02	.02	.00	-.03	**-.08**	.01	**.06**	**-.10**	**-.12**	**-.06**	-.04	**-.40**	—					
22.	Wake-Time After Sleep Onset	.03	.02	-.03	**.06**	.05	.02	**.07**	**.06**	**-.10**	**-.13**	-.05	-.01	-.00	.00	.00	.01	**-.06**	**-.07**	**.07**	**.17**	-.00	—				
23.	Daytime Fatigue	**.05**	-.02	**-.10**	**.14**	**.16**	.03	**.04**	**.19**	.01	.01	**.15**	-.03	.01	.03	.01	**.23**	**.26**	**.25**	**.29**	**.15**	-.03	.05	—			
24.	Alcohol Quantity	**.05**	**.11**	**.07**	-.02	-.03	**.05**	-.02	-.01	**.25**	**.21**	**.21**	**.15**	.05	**.04**	-.02	**-.05**	**-.12**	**-.05**	**-.04**	**.04**	-.03	-.03	-.01	—		
25.	Negative Alcohol Consequences	**.06**	**.09**	.03	**.04**	-.01	.01	-.03	**.06**	**.16**	**.10**	**.23**	**.06**	**.08**	**.05**	.02	.03	**-.04**	-.02	**.08**	**.10**	**-.06**	-.03	.03	**.53**	—	
26.	Cannabis Frequency	.01	**.44**	**.17**	-.00	**-.05**	**-.16**	.02	-.03	.02	**.04**	**.05**	**.56**	**.41**	.03	**.40**	.00	**-.05**	-.03	**.07**	**-.06**	-.01	.01	-.04	**.13**	**.10**	—
27.	Negative Cannabis Consequences	**.04**	**.29**	**.08**	.01	**-.05**	-.00	.02	**.05**	**.09**	**.09**	**.09**	**.36**	**.28**	**.04**	**.42**	**.06**	.02	**.09**	**.15**	**-.04**	**.05**	-.01	**.06**	.02	**.13**	**.46**

Note. $N = 217$. Pearson's correlation coefficients are reported for two continuous variables; Spearman's coefficients (r_s) are reported for continuous and dichotomous variables; Phi coefficients (r_φ) are reported for two dichotomous variables. Significant correlation coefficients at $p < .05$ are highlighted in bold font.

Table 3
Multilevel Models of Daily Alcohol Sleep Aid Use Predicting Sleep- and Substance-Related Outcomes

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Wake-time After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Alcohol Consequences	
	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	IRR	Estimate (*SE*)
Fixed Effects						
Level 2 (Between-Person)						
Intercept	1.63 (0.06)***	7.36 (0.12)***	14.41 (2.33)***	2.62 (0.08)***	0.07	-2.67 (0.31)***
Alcohol Sleep Aid Use	**-0.97 (1.57)**	**1.76 (3.24)**	**-14.74 (59.91)**	**0.47 (2.32)**	**0.06**	**-2.77 (3.82)**
Male Sex	0.06 (0.12)	-0.61 (0.25)*	-3.55 (5.19)	0.09 (0.18)	0.82	-0.20 (0.37)
Age	0.07 (0.05)	0.00 (0.10)	1.09 (1.94)	-0.00 (0.07)	0.99	-0.02 (0.13)
Negative Affect	0.05 (0.02)**	-0.07 (0.04)*	-0.01 (0.72)	0.09 (0.03)**	1.20	0.19 (0.06)**
Alcohol Quantity	0.04 (0.04)	0.01 (0.08)	-0.57 (1.77)	0.03 (0.06)	2.15	0.77 (0.13)***
Level 1 (Within-Person)						
Alcohol Sleep Aid Use	**0.65 (0.39)**	**-0.11 (0.83)**	**-3.38 (13.33)**	**0.62 (0.43)**	**2.05**	**0.72 (0.79)**
Alcohol Sleep Aid Use (Lagged)	**0.03 (0.35)**	**0.24 (0.76)**	**0.30 (9.88)**	**-0.28 (0.40)**	**0.48**	**-0.73 (0.71)**
Study Days	0.12 (0.07)	0.08 (0.15)	2.60 (3.65)	-0.24 (0.08)**	0.78	-0.25 (0.30)
Weekend (Friday & Saturday)	-0.17 (0.08)*	0.31 (0.17)	1.62 (2.89)	0.00 (0.08)	8.66	2.16 (0.27)***
Negative Affect	0.04 (0.01)**	-0.05 (0.03)	-0.32 (0.53)	0.03 (0.02)	1.01	0.01 (0.07)
Negative Affect (Lagged)	0.03 (0.01)*	-0.04 (0.03)	0.29 (0.56)	0.00 (0.02)	1.01	0.01 (0.07)
Alcohol Quantity	0.04 (0.01)**	-0.06 (0.03)*	-0.37 (0.50)	-0.00 (0.01)	0.89	-0.12 (0.04)**
Alcohol Quantity (Lagged)	-0.02 (0.01)	0.02 (0.03)	0.07 (0.45)	0.03 (0.01)*	0.86	-0.15 (0.04)***
Random Effects						
Level 2 (Between-Person)						
Intercept	0.11 (0.03)***	0.43 (0.13)***	184.84 (49.19)***	0.27 (0.07)***	1.52	0.42 (0.21)
Study Days	—	0.35 (0.23)	470.99 (150.18)**	—	3.27	1.19 (0.95)
Level 1 (Within-Person)						
Residual	0.71 (0.04)***	3.20 (0.18)***	304.99 (36.31)***	0.92 (0.06)***		
Autocorrelation	0.14 (0.04)***	0.09 (0.05)*	0.24 (0.11)*	0.21 (0.05)***		

Note. $n = 83$. Sleep aid use predictors highlighted in bold font. Results of Negative Alcohol Consequences (dispersion parameter = 3.30, $SE = 1.05$, $p = .002$) model is based on negative binomial multilevel models and incidence rate ratios (IRR) are reported.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4
Multilevel Models of Daily Cannabis Sleep Aid Use Predicting Sleep- and Substance-Related Outcomes

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Wake-time After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Cannabis Consequences	
	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	IRR	Estimate (*SE*)
Fixed Effects						
Level 2 (Between-Person)						
Intercept	1.62 (0.06)***	7.30 (0.12)***	15.65 (2.39)***	2.57 (0.08)***	0.03	-3.41 (0.36)***
Cannabis Sleep Aid Use	**-0.46 (0.31)**	**1.48 (0.61)***	**-8.89 (12.27)**	**0.56 (0.46)**	**18.87**	**2.94 (1.27)***
Male Sex	0.12 (0.12)	-0.56 (0.23)*	-4.30 (5.06)	0.18 (0.17)	3.02	1.10 (0.53)*
Age	0.06 (0.05)	0.03 (0.09)	0.34 (1.85)	0.03 (0.07)	1.00	-0.00 (0.20)
Negative Affect	0.05 (0.02)**	-0.08 (0.03)*	-0.13 (0.72)	0.09 (0.03)***	1.12	0.11 (0.10)
Cannabis Frequency	0.05 (0.07)	-0.22 (0.14)	4.81 (3.01)	-0.16 (0.11)	1.86	0.62 (0.36)
Tobacco Frequency	-0.04 (0.03)	0.06 (0.06)	-1.76 (1.12)	0.01 (0.04)	1.07	0.07 (0.08)
Level 1 (Within-Person)						
Cannabis Sleep Aid Use	**-0.06 (0.14)**	**0.62 (0.30)***	**-13.27 (4.59)****	**0.34 (0.17)***	**1.34**	**0.29 (0.29)**
Cannabis Sleep Aid Use (Lagged)	**0.04 (0.14)**	**-0.08 (0.30)**	**4.06 (4.55)**	**-0.07 (0.16)**	**0.81**	**-0.22 (0.26)**
Study Days	0.09 (0.06)	0.14 (0.15)	1.87 (3.68)	-0.24 (0.08)**	0.39	-0.94 (0.32)**
Weekend (Friday & Saturday)	-0.07 (0.07)	0.13 (0.15)	1.34 (2.45)	-0.02 (0.08)	0.70	-0.36 (0.22)
Negative Affect	0.04 (0.01)**	-0.05 (0.03)	-0.49 (0.53)	0.03 (0.02)	0.93	-0.07 (0.05)
Negative Affect (Lagged)	0.03 (0.01)*	-0.04 (0.03)	0.26 (0.55)	-0.00 (0.02)	1.05	0.05 (0.05)
Cannabis Frequency	-0.02 (0.04)	0.04 (0.08)	0.36 (1.23)	0.03 (0.05)	1.17	0.16 (0.07)*
Cannabis Frequency (Lagged)	-0.05 (0.04)	0.11 (0.08)	-0.19 (1.20)	-0.16 (0.11)	1.13	0.13 (0.08)
Tobacco Frequency	-0.00 (0.06)	0.22 (0.12)	0.80 (2.09)	0.13 (0.07)	0.98	-0.02 (0.08)
Tobacco Frequency (Lagged)	0.09 (0.06)	-0.36 (0.12)**	-0.32 (1.83)	0.05 (0.07)	1.05	0.05 (0.09)
Random Effects						
Level 2 (Between-Person)						
Intercept	0.10 (0.03)***	0.38 (0.11)**	190.16 (49.49)***	0.26 (0.07)***	9.91	2.29 (0.73)**
Study Days	—	0.38 (0.24)	492..46 (153.40)**	—	4.14	1.42 (0.78)
Level 1 (Within-Person)						
Residual	0.71 (0.04)***	3.12 (0.18)***	288.91 (34.17)***	0.89 (0.05)***		
Autocorrelation	0.12 (0.04)**	0.08 (0.05)	0.21 (0.11)	0.18 (0.05)***		

Note. $n = 83$. Sleep aid use predictors highlighted in bold font. Results of Negative Cannabis Consequences (dispersion parameter = 0.00, $SE = 0.01$, $p = .99$) model is based on negative binomial multilevel models and incidence rate ratios (IRR) are reported.
*$p < .05$. **$p < .01$. ***$p < .001$.

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Vita

PATRICIA A. GOODHINES

Education

2015 – Present Syracuse University, Syracuse, NY
Ph.D. Clinical Psychology
Advisor: Aesoon Park, Ph.D.

2013 St. Lawrence University, Canton, NY
B.S., Psychology with honors, *magna cum laude*

Research Interests

- Self-medication and substance use for management of psychiatric symptoms
- Etiology and reciprocal influences of substance use and sleep disorder comorbidities in adolescence and young adulthood

Publications

Goodhines, P. A., Gellis, L. A., Kim, J., Fucito, L. M., & Park, A. (2017). Self-medication for sleep in college students: Concurrent and prospective associations with sleep and alcohol behavior. *Behavioral Sleep Medicine*. Advance online publication. doi:10.1080/15402002.2017.1357119

National Presentations

Goodhines, P. A., Gellis, L. A., Park, A. (2018, June). *Alcohol and cannabis use for sleep aid in college students: A daily diary investigation*. Poster presented at the 32nd annual meeting of the American Professional Sleep Societies (SLEEP), Baltimore, MD.

Goodhines, P. A., Park, A., & Gellis, L. (2017, June). *Interaction between risky drinking patterns and insomnia diurnal impact on subsequent negative drinking consequences in college students*. Poster presented at the 40th annual meeting of the Research Society on Alcoholism, Denver, CO.

Goodhines, P. A., Park, A., Gellis, L., Loury, J., & Kim, J. (2016, June). *Substance use for sleep aid in college students: Associations with risky drinking and insomnia severity*. Poster presented at the 39th annual meeting of the Research Society on Alcoholism, New Orleans, LA.

Thacher, P.V. & **Goodhines, P.** (2013, June). *An examination of university students' patterns of substance use to manipulate sleep and wake states*. Poster presented at the 27th annual meeting of the American Professional Sleep Societies (SLEEP), Baltimore, MD.